EVANSVILLE WATER AND SEWER UTILITY
AND
FOUR RIVERS RESOURCE CONSERVATION
AND DEVELOPMENT AREA, INC.

Volume 2
McFADDEN CREEK BIOASSESSMENT

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

October 2000

PIGEON CREEK
WATERSHED DIAGNOSTIC STUDY
VOL. 2 – MCFADDEN CREEK BIOASSESSMENT

Prepared for

Evansville Water and Sewer Utility
And
Four Rivers Resource Conservation and Development
Area, Inc.

By

HARZA
Engineering Company

October 2000

EXECUTIVE SUMMARY

The overall objectives of this diagnostic study are to identify sources of pollution in the Pigeon Creek watershed study area, and, to recommend land management projects, institutional reforms, and potential financing for pollution mitigation. McFadden Creek, a stream in the same hydrologic unit (Highland-Pigeon), was characterizeded to rank subwatersheds for nonpoint source control investment.

Chemical, biological, and habitat surveys were performed at ten sampling stations in McFadden Creek and its tributaries. Water quality analyses found supersaturated dissolved oxygen concentrations, generally high nutrient and suspended solids concentrations, and high fecal coliform bacteria counts. Supersaturated oxygen levels indicate high levels of primary production, as stimulated by nutrient loadings from the watershed. Physical habitat surveys performed using the Ohio EPA's Qualitative Habitat Evaluation Index, QHEI, were also performed. The lower portions of McFadden Creek generally have better physical habitat than the upper reaches or tributaries, many of which have been channelized and straightened. We attribute this to higher scores for substrate, riparian habitat, and gradient in the lower reaches. To evaluate the biological community, we utilized the US EPA's Rapid Bioassessment Protocol II (RBP II). RBP II utilizes systematic field collection and analysis of benthic macroinvertebrates at the family taxonomic level.

We noted the following general trends from downstream to upstream reaches and tributaries:

- Increased DO supersaturation
- Increased nitrate nitrogen concentrations
- Degraded physical habitat, particularly in the substrate and riparian ratings

We judged the key stream indicators of watershed health to be coliform bacteria counts, nitrogen concentrations, suspended solids, the QHEI scores and FBI, the Family Biotic Index. Phosphorus concentrations were essentially identical among the stations, so that measure was judged not to distinguish between sites. Higher QHEI scores indicate improved habitat conditions. The FBI, one of the metrics in the RBP II, was selected as the key benthic indicator as it incorporates both diversity and pollution tolerance. Lower FBI scores are an indicator of an aquatic system under less stress.

SUMMARY OF TRIBUTARY HEALTH INDICATORS

Site	Subwatershed	*E. coli* (cfu/100mL)	Ammonia N (mg/L)	Nitrate N (mg/L)	Suspended Solids (mg/L)	Siltation	QHEI Score	FBI
MF-1	Mainstem	300	0.11	2.2	28	Normal	52	7.14
MF-2	Mainstem	280	0.16	2.2	35	Normal	63	7.28
MF-3	Tributary	180	0.54	1.5	16	Moderate	48	7.54
MF-4	Tributary	1,200	0.41	4.8	6	Normal	56	6.41
MF-5	Mainstem	380	0.34	1.6	76	Moderate	52	7.32
MF-6	Tributary	700	0.57	<0.05	83	Moderate	46	7.92
MF-7	Mainstem	150	<0.03	1.8	68	Normal	48	6.88
MF-8	Mainstem	240	0.15	3.3	120	Moderate	39	7.74
MF-9	Tributary	180	0.26	3.6	10	Moderate	42	7.58
MF-10	Tributary	23	0.81	3.5	3.5	Heavy	33	7.83

We used these data to rank these sites according to the level of ecological stress each was being subjected to, and, to recommend a relative ranking of subwatersheds on the basis of relative need for nonpoint source controls. Categories of high, moderate and low priorities indicate Harza's opinion on relative need for agricultural nonpoint source controls.

RELATIVE PRIORITIES FOR AGRICULTURAL NONPOINT SOURCE CONTROL INVESTMENT

Priority	Stations
High	MF-10 MF-4 MF-8 MF-9
Moderate	MF-7 MF-5 MF-6 MF-3
Low	MF-1 MF-2

PIGEON CREEK
WATERSHED DIAGNOSTIC STUDY

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF TABLES

1.0 INTRODUCTION

Volume 2 of the Pigeon Creek Watershed Diagnostic Report focuses on McFadden Creek in Posey County, and is limited to a bioassessment we performed of this small watershed in May, 2000. This chapter of Volume 2 of the Pigeon Creek Watershed Diagnostic Report describes the study objectives, provides general information and details historical data for the study area.

1.1 OBJECTIVES

The overall objectives of this diagnostic study are to identify sources of pollution in the Pigeon Creek watershed study area, and, to recommend land management projects, institutional reforms, and potential financing for pollution mitigation. McFadden Creek is a neighboring stream in the same hydrologic unit (Highland-Pigeon). The specific objective for the McFadden Creek portion of this study was to assess water quality using chemical, physical and biological indicators.

1.2 LOCATION

McFadden Creek is located in Posey County, Indiana. The study area is shown in Exhibit 1. McFadden Creek is tributary to the Ohio River. The Highland-Pigeon watershed is USGS Cataloging Unit 05140202.

McFadden Creek is classified as a navigable stream from its junction with the Ohio River upstream for 2.3 river miles.

1.3 WATERSHED SIZE AND TOPOGRAPHY

The McFadden Creek watershed is approximately 11,974 acres. According to *Ecoregions and Subregions of the United States* (McNab and Ayers 1994) McFadden Creek is located in the Interior Plateau Section, Eastern Broadleaf Forest Province of the Hot Continental Division. The Interior Plateau Section is made up of many wide, flat-bottomed terraced valleys, forested valley walls, and dissected glacial till plains. Local topographic relief in the drainage is low, with land slopes rarely exceeding 1.5%.

The region's natural vegetation is dominated by broadleaf deciduous forest, but the amounts of precipitation favor the drought-resistant oak-hickory association. The oak-hickory forest in southern Indiana forms a mosaic pattern with prairie.

1.4 LEGAL DRAINS

The Indiana statute at IC 36-9-27 contains the County Drainage Code. This law authorizes county drainage boards to regulate certain drains. The intent of this law is to increase the hydraulic efficiency of waterways and control upstream ponding and flooding. The county surveyor is the technical authority on the construction, reconstruction, and maintenance of all regulated drains or proposed regulated drains in the county. The County Drainage Code requires the county surveyor to classify regulated drains in the county as:

1. Drains in need of reconstruction;
2. Drains in need of periodic maintenance; or
3. Drains that should be vacated.

The county drainage boards across the state fund reconstruction and maintenance of regulated drains. Among the board's duties, as defined in the statute, is the reconstruction of regulated drains that do not properly function and may require erosion control or grade stabilization structures. This is an avenue for implementing watershed management projects that is underutilized in the state.

Much of McFadden Creek, including Reuger Ditch, is considered a legal drain. Watershed management projects affecting drainage in these channels will require the approval of the County Drainage Board.

1.5 GEOLOGY AND SOILS

The Interior Plateau Section includes gentle hills and broad valleys, gently rolling lowland plains, and bottom lands along major rivers, with associated terraces and meander scars. A notable but very minor landform is anthropogenic. lands that have been strip-mined exhibit humocky or ridge-swale topography. Soils were formed under deciduous forests from loess and alluvium. The soils are dominated by Ultisol and Alfisol soil orders. Soils in the McFadden Creek valley are generally poorly drained.

1.6 LAND COVER

Land cover information was obtained in digital format from the Indiana Gap Project, a part of the national Gap efforts (Scott and Jennings 1997). The Indiana land cover data layer was derived from 30 m Thematic Mapper. It was completed in 2000 and is being used in numerous projects under way by the Indiana Biodiversity Initiative and other organizations.

Land use/land cover in the McFadden Creek watershed is principally row crop agriculture, as illustrated in Exhibit 2 and Table 1. Agriculture in this watershed is essentially corn and soybean production, with limited pasture and hay fields.

Table 1

MCFADDEN CREEK WATERSHED LAND COVER
(Source: Indiana Gap Project)

LAND USE	AREA (acres)	PERCENTAGE
Non-vegetated	137	1.1
Urban High Density	105	0.9
Urban Low Density	86	0.7
Agriculture Row Crop	9,815	82
Agriculture Pasture/Grassland	1,070	8.9
Forest Deciduous	534	4.5
Wetland Forest	133	1.1
Wetland Woodland	9	0.1
Wetland Shrubland	15	0.1
Wetland Herbaceous	23	0.2
Wetland Sparsely Vegetated	11	0.1
Water	36	0.3
Total	**11,974**	**100**

1.7 POINT SOURCE POLLUTION

There is one permitted point source discharge in the McFadden Creek watershed. It is for a small domestic wastewater treatment plant located south of State Highway 62 on McFadden Creek. The owner is Creekside Court Mobile Home Park, of Mount Vernon, IN. The NPDES Permit Id. is IN0039616, expiring September 30, 2001. They are required under this permit to monitor dissolved oxygen, pH, ammonia nitrogen, total suspended solids, treatment plant flow, residual chlorine, biochemical oxygen demand (BOD), and bypassed flow.

2.0 WATERSHED BIOASSESSMENT

During May 2000, we collected field data to characterize the watershed. Chemical, biological and habitat surveys were performed at our ten sampling stations (Exhibit 3, Table 2). These samples were analyzed and used to characterize tributary subbasins.

Table 2

MCFADDEN CREEK BIOASSESSMENT SAMPLING SITES

STATION	DESCRIPTION	RATIONALE
MF-1	McFadden Creek at SR62	Most downstream most site
MF-2	McFadden Creek at unnamed trestle bridge	Historic fly dumping site
MF-3	Second (unnamed) tributary	Tributary mouth; drains agricultural and subdivision areas
MF-4	Fourth (unnamed) tributary	Large agricultural subbasin
MF-5	McFadden Creek at 350 East Bridge	Downstream of NPDES discharge
MF-6	Fifth (unnamed) tributary	Large agricultural subbasin
MF-7	McFadden Creek at SR62	Upstream of NPDES discharge
MF-8	McFadden Creek at 500 East Bridge	Channelized reach
MF-9	Eleventh (unnamed) tributary, at 600 East Bridge	Channelized reach; agricultural drainage with numerous oil wells
MF-10	Tenth (unnamed) tributary	Agricultural drainage; numerous oil wells

2.1 METHODS

Methods of sample collection, handling and analysis were presented in the QAPP (Harza 1999). Briefly, surface water quality was field tested for dissolved oxygen, temperature, and conductivity during the collection of aquatic biota. Temperature was measured using a mercury thermometer, dissolved oxygen (DO) with a Yellow Springs Instrument (YSI) Co. Model 57 DO meter and conductivity with a YSI Model 33 Salinity-Conductivity-Temperature meter. Grab samples collected for analysis of nitrate nitrogen, total Kjeldahl nitrogen, ammonia nitrogen, pH, total phosphorus, BOD_5, suspended solids, and

E. coli. Water samples collected during this study were driven to Central States Analytical Laboratory in Evansville the day they were sampled. The laboratory reports can be found in Appendix B of Volume 3. Analytical methods and detection limits required in the QAPP are given in Table 3. Samples were analyzed by Central States Analytical Lab of Evansville, Indiana.

Physical habitat measurements were made at each sampling site using the procedures described in OEPA (1989) and included in the QAPP. Each sampling site was photodocumented at the upstream and downstream termini of the reach. Channel distance measurements were taken with a metric tape measure. Depth and current velocity measurements will be made using a Marsh-McBirney digital flow meter.

The health of the benthic community was assessed utilizing the Rapid Bioassessment Protocol II method (Plafkin *et al.* 1989). The collection procedure was performed at comparable habitat types at all sites, supplemented with separate Coarse Particulate Organic Matter (CPOM) samples. The RBP II focused on riffle/run habitat because it is the most productive habitat available in stream systems and includes many pollution sensitive taxa of the scraper and filtering collector functional feeding groups. The CPOM sampling provides a measure a third trophic component of the benthos, the shredders.

Table 3

ANALYTICAL METHODS, APPLICABLE WATER QUALITY STANDARDS AND METHOD DETECTION LIMITS

Parameter	Method[1]	Aquatic Life Standard	Method Detection Limit
Dissolved oxygen	4500-O	>4mg/L	0.5mg/L
PH	$4500\text{-}H^+$	6 - 9	±0.1
Total suspended solids	2540 (D)		
Ammonia nitrogen	$4500\text{-}NH_3$ (F)		0.03 mg N/L
Nitrate nitrogen	$4500\text{-}NO_3$ (C)		0.05 mg N/L
Total Kjeldahl nitrogen	$4500\text{-}N_{org}$ (B)		
Total phosphorus	6010A		20 µg/L
Biochemical oxygen demand	5210 (B)		2 mg/L
Escherichia coli	9213 (D)	125/100mL [2]	
Arsenic	6010A	190 µg/L (Ar III)	53 µg/L
Cadmium	6010A	1.1 µg/L [3]	4 µg/L
Chromium	6010A	207 µg/L [3] (Cr III)	7 µg/L
Copper	6010A	12 µg/L [3]	6 µg/L
Lead	6010A	3 µg/L [3]	40 µg/L
Nickel	6010A	158 µg/L [3]	15 µg/L
Zinc	6010A	106 µg/L [3]	2 µg/L

[1] From APHA *et al.* 1992 or EPA's SW-846

[2] Recreational standard

[3] Assuming 100 mg/L hardness

2.2 CHEMICAL QUALITY

Water quality samples for analysis in the laboratory were collected during a period of low flow at the ten subwatershed sites. Additionally, telemetry equipment was used to measure some water quality parameters in the field (Table 4).

Table 4

IN-SITU WATER QUALITY DATA

Site	Waterbody	Sampling Date	Temp (°C)	Conductivity (umhos/cm)	pH	DO (mg/L)	% DO Saturation
MF-1	McFadden Creek	5/11/00	19.1	642	7.93	14.9	164%
MF-2	McFadden Creek	5/11/00	20.1	628	7.98	14.8	161%
MF-3	Second Tributary*	5/11/00	21.2	534	8.08	17.8	199%
MF-4	Fourth Tributary*	5/11/00	22.4	649	8.22	19.0	220%
MF-5	McFadden Creek	5/13/00	22.7	599	7.90	14.0	165%
MF-6	Fifth Tributary*	5/13/00	21.6	593	7.70	12.1	137%
MF-7	McFadden Creek	5/13/00	23.4	617	7.94	15.0	179%
MF-8	McFadden Creek	5/13/00	23.9	612	8.20	18.0	220%
MF-9	Eleventh Tributary*	5/9/00	24.6	541	8.90	30.0	370%
MF-10	Tenth Tributary*	5/9/00	24.8	681	8.61	33.0	400%

* Tributaries are denoted numerically from downstream to upstream, totaling 13.

2.2.1 Conductivity

Conductivity is the ability of water to carry an electric current and depends on the concentration of dissolved ions. It is an indirect measure of the dissolved solids in the water. Typical dissolved solids include salts, organic materials, and nutrients. In McFadden Creek, field measurements of conductivity ranged from 534 μhos/cm at MF-3 to 681 μhos/cm at MF-10, the most upstream monitoring site. MF-10 is in an area with numerous oil wells, and the relatively high conductivity values there could reflect that land use.

Table 5

LABORATORY WATER QUALITY DATA

Site	*E. coli* (cfu/100ml)	Total Kjeldahl Nitrogen (mg/L)	Nitrate (mgN/L)	Ammonia (mgN/L)	Phosphorus (mg/L)	BOD (mg/L)	Total Suspended Solids (mg/L)
MF-1	300	1.5	2.2	0.11	0.39	<2.5	28
MF-2	400	1.1	2.3	0.09	0.39	<2.5	36
MF-3	180	<1.0	1.5	0.54	0.32	<2.5	16
MF-4	1,200	3.9	4.8	0.41	0.36	<2.5	6
MF-5	380	2.1	1.6	0.34	0.38	<2.5	76
MF-6	700	<1.0	<0.05	0.57	0.38	<2.5	83
MF-7	150	2.1	1.8	<0.03	0.38	<2.5	68
MF-8	240	1.8	3.3	0.15	0.41	<2.5	120
MF-9	180	<1.0	3.6	0.26	0.33	<2.5	10
MF-10	23	1.3	3.5	0.81	0.26	3.3	3.5

2.2.2 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in the water column available to support aquatic life. DO levels near the saturation point indicate conditions favorable for a variety of life. Water with low DO levels is only able to support a few species. Streams absorb oxygen directly from the air and from aquatic plants undergoing photosynthesis. Supersaturated, DO concentrations (>100%) generally indicate nutrient enrichment, with the elevated photosynthesis causing the very high levels. Indiana's surface water quality standards dictate that DO levels shall average at least 5 mg/L per day and at no time should levels fall below 4 mg/L. Field measurements of dissolved oxygen were taken at each sampling point.

DO ranged from 12.1 mg/L at MF-6 to 33 mg/L at MF-10. While all DO levels measured were well above the standard of 5 mg/L, indicating that the streams have enough oxygen to support diverse aquatic communities, all sites were supersaturated. The percent DO saturation ranged from 138% to 393%. Oxygen supersaturation in low-gradient streams generally indicates nutrient enrichment in the waters. The high concentrations of DO are a result of photosynthesis from abundant attached filamentous algae.

2.2.3 Temperature

Water temperature is important to aquatic life in a stream. As temperatures in the stream rise, less oxygen is available for aquatic organisms. Increased temperatures can cause an increase in metabolic and reproductive rates throughout the food chain. Some species have a specific range of temperatures in which they will survive, so large variations in temperature could threaten aquatic communities. Temperature ranged from 19.1°C to 24.8°C.

2.2.4 pH

Water's hydrogen ion concentration is expressed as pH. Measurements below neutral, pH 7.0, indicate higher hydrogen ion concentrations and that the water is acidic. Conversely, pH values above 7.0 show that the water is basic. Many aquatic organisms are sensitive to fluctuations in pH, and their reproduction processes are impeded under very acidic or very basic conditions in the water. Indiana's surface water standard dictate that pH should be in the range of 6–9, and variations exceeding 9 will be permitted if associated with photosynthetic activity. Field measurements of pH ranged from 7.70 to 8.90, and were well within the standard.

Variations in pH are caused largely by changes in carbonic acid in the water. Carbonic acid is formed as a result of the dissolution of carbon dioxide into water. When all the free carbon dioxide in the water column is utilized, the carbonic acid is consumed by algae and aquatic macrophytes. This removal of carbonic acid from the water column results in a more basic composition, or a higher pH value. Waters that have measured pH values above 8.0 generally are undergoing an algal bloom. In such instances, high demand for carbon dioxide by the increasing algae population reduces the carbonic acid in the lake, thus making the water basic. High pH values measured at several locations were consistent with dissolved oxygen supersaturation at those locations, supporting the cause of the high pH values to be photosynthesis.

2.2.5 Coliform Bacteria

Escherichia coli is the most widely known member of the coliform group of bacteria. *E. coli* is abundant in fecal matter and is often used as an indicator of sanitary discharges and pathogenic organisms. *E. coli* is estimated colony forming units (cfu) per 100ml of sample. Indiana's standard for recreational waters states:

> "E. coli bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) colony forming units per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) colony forming units per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period" (IAC 327 2-1-6).

Concentrations of *E. coli* in samples taken on May 11, 2000 ranged from 23 cfu/100ml at MF-10 (most upstream site) to 1,200 cfu/100mL at MF-4, a tributary. Six of the ten sites exceeded the 235 cfu/100 mL standard. Coliform bacteria counts in natural waters usually have a high variability. Our study involved a single grab sample, which may not accurately characterize the coliform loadings in subwatersheds. Nevertheless, sites MF-4 and MF-6, both on agricultural subwatersheds, have high concentrations of *E. coli* that warrant additional investigation.

2.2.6 Nitrogen

Nitrogen is also an essential nutrient in plant and animal growth, however in high concentrations it can inhibit such development. Natural waters contain nitrogen in the form of organic (or biomass) nitrogen, or in inorganic forms such as nitrate (NO_3), or nitrite (NO_2). In aerobic waters nitrate is usually the predominant form. Nitrogen can enter the stream through stormwater runoff from lands applied with fertilizer. In this study, nitrate and nitrite, and total Kjeldahl nitrogen were measured. Kjeldahl nitrogen is a measure of organic plus ammonia nitrogen. Ammonia nitrogen is commonly used as an indicator of sewage contamination.

The surface water quality standard set by the State for nitrite and nitrate is a maximum of 10 mg/L. This standard is intended to protect drinking water use. Nitrate nitrogen values ranged from <0.05 mg/L in MF-6 (at tributary) to 4.8 mg/L at MF-4, another tributary. Kjeldahl nitrogen ranged from <1.0 mg/L at four sites to 3.9 mg/L at MF-4. Ammonia nitrogen ranged from <0.03 mg/L at MF-7 to 0.81 mg/L at MF-10. Exhibits 5, 6, and 7 show the concentrations of the three forms of nitrogen at each sampling location.

2.2.7 Phosphorus

Phosphorus is also an essential nutrient for plant and animal growth. Excessive concentrations of phosphorus in the water column can lead to eutrophication of the stream. Total phosphorus was analyzed in this study. Total phosphorus is commonly used as a measure of the trophic status of a water body. Total phosphorus is a measure of both particulate and dissolved phosphorus. A mechanism by which total phosphorus enters the stream is through land-applied fertilizer. Phosphorus particles become bound to the soil, and as surface runoff carries these particles to the stream, the phosphorus tends to remain in particulate form.

The range of total phosphorus concentrations was from 0.26 mg/L at MF-10 to 0.41 mg/L at MF-8. Exhibit 8 shows the total phosphorus levels at each sampling location. Phosphorus concentrations were not significantly different among the ten sampling sites, suggesting that areal phosphorus loading is similar in the subwatersheds.

2.2.8 Biochemical Oxygen Demand

Oxidation of organic or inorganic materials in an aerobic environment utilizes oxygen. In the laboratory, samples are incubated at 23°C for five days to define the biochemical oxygen demand (BOD_5). BOD_5 was below the detection limit in eight of the ten samples. At MF-10, BOD_5 was 3.3 mg/L.

2.2.9 Suspended Solids

Particles suspended in the water may be living (such as plankton or bacteria) non-living organic material (such as leaf litter) or mineral particles. Some of this material is the base of the aquatic food chain. Some is the result of upland soil loss.

We observed a wide range of concentrations of total suspended solids in McFadden Creek. Three sites were at or below 10 mg/L (MF-10, MF-9, MF-4). The highest samples were MF-8 at 120 mg/L, MF-6 at 83 mg/L, MF-5 at 76 mg/L and MF-7 at 68 mg/L, all of which were sampled on May 13, 2000. Field notes and photos indicate that May 12 and

13 were both clear, sunny days, although it did rain lightly during the night of the week of sampling.

2.3 PHYSICAL HABITAT

2.3.1 Streamflow

Flow measurements were taken using a Marsh McBirney model 201 portable flow meter. Flow measurements were made immediately following water and benthic sample collection (Table 6).

Table 6

STREAMFLOW MEASUREMENTS

Site	Water body	Discharge (ft^3/sec)
MF-1	McFadden Creek	2.4
MF-2	McFadden Creek	2.3
MF-3	Second Tributary*	0.4
MF-4	Fourth Tributary*	0.2
MF-5	McFadden Creek	Too deep to wade
MF-6	Fifth Tributary*	0.8
MF-7	McFadden Creek	1.6
MF-8	McFadden Creek	1.8
MF-9	Eleventh Tributary*	0.7
MF-10	Tenth Tributary*	0.2

* Tributaries are denoted numerically from downstream to upstream

2.3.2 Qualitative Habitat Evalution

Physical habitat was evaluated utilizing the Ohio EPA's Qualitative Habitat Evaluation Index (Rankin 1989). A 300-foot section of each of the ten stream sites was assessed by a two-person field team. During the Qualitative Habitat Evaluation Index (QHEI) evaluation, scores are recorded for seven physical habitat metrics and the results are summed. These qualitative parameters include: substrate, instream cover, channel morphology, riparian zone and bank erosion, pool and glide quality, riffle and run quality, and gradient.

QHEI reflects the quality of stream physical habitat. In this procedure, the highest scores are assigned to the habitat parameters that have been shown to be correlated with streams having high biological diversity and integrity (Rankin 1989). Progressively lower scores are assigned to less desirable habitat features.

Table 7 and Exhibit 8 show the QHEI results. Appendix C contains the QHEI field data sheets. Photographs taken during the field investigation are contained in Appendix D.

The lower portions of McFadden Creek generally have better physical habitat than the upper reaches or tributaries. This can be attributed to higher scores for substrate, riparian habitat, and gradient. The highest overall QHEI scores were measured to be at MF-2, MF-4, MF-1, and MF-5. The forested wetland land cover (Exhibit 2) along the stream in its lower reaches reflect the higher riparian habitat scores.

Table 7

QUALITATIVE HABITAT EVALUATION INDEX

Site	Water body	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	QHEI
MF-1	McFadden Creek	10	7	7	9	7	2	10	52
MF-2	McFadden Creek	16	9	8	12	7	1	10	63
MF-3	Second Tributary*	14	7	8	10	4	1	4	48
MF-4	Fourth Tributary*	16	8	10	10	4	2	6	56
MF-5	McFadden Creek	5	4	9	12	8	4	10	52
MF-6	Fifth Tributary*	4	6	9	9	6	4	8	46
MF-7	McFadden Creek	7	7	9	8	8	5	4	48
MF-8	McFadden Creek	5	7	7	6	6	4	4	39
MF-9	Eleventh Tributary*	12	6	6	6	4	4	4	42
MF-10	Tenth Tributary*	3	4	6	6	3	1	10	33

* Tributaries are denoted numerically from downstream to upstream.

Agricultural land uses without conservation buffers along stream corridors have higher rates of sedimentation than other land uses. Fine silt particles are transported by overland flow to streams where they are carried by the flow until deposited on the substrate. The adverse effects of sedimentation include burial of aquatic vegetation, macroinvertebrates and substrate interstial spaces. In the QHEI, there are two means of scoring substrate quality. One involves the amount of silt cover on the substrate. The second is the embeddness by silt particles on rocks and leaves on the surface of the substrate. QHEI scoring of substrate quality is tabulated below. Again, higher values are indicative of increase in habitat quality, and, in the QHEI system, points are deducted for siltation.

Table 8

SUBSTRATE QUALITY SCORING

Site	Waterbody	Silt Cover (points)	Extent of Embeddness (points)
MF-1	McFadden Creek	Silt normal (0)	Moderate (-1)
MF-2	McFadden Creek	Silt normal (0)	Low (0)
MF-3	Second Tributary*	Silt moderate (-1)	Moderate (-1)
MF-4	Fourth Tributary*	Silt normal (0)	Low (0)
MF-5	McFadden Creek	Silt moderate (-1)	Moderate (-1)
MF-6	Fifth Tributary*	Silt moderate (-1)	Moderate (-1)
MF-7	McFadden Creek	Silt normal (0)	Low (0)
MF-8	McFadden Creek	Silt moderate (-1)	Moderate (-1)
MF-9	Eleventh Tributary*	Silt moderate (-1)	Moderate (-1)
MF-10	Tenth Tributary*	Silt heavy (-2)	Extensive (-2)

2.4 MACROINVERTEBRATE COMMUNITIES

The US EPA's Rapid Bioassessment Protocol II (RBP II) utilizes the systematic field collection and analysis of major benthic taxa. This protocol is appropriate for prioritizing sites for more intensive evaluation. RBP II incorporates the concept of benthic analysis at the family taxonomic level. The technique utilizes field sorting and identification. The biological survey of RBP II uses standardized sampling of benthic macroinvertebrates, supplemented by a cursory field observation of other aquatic biota such as periphyton, macrophytes, slimes and fish. The collection procedure provides representative samples of the macroinvertebrate fauna from riffle and run habitat types, and is supplemented with separate Course Particulate Organic Matter (CPOM) samples for the analysis of shredders and nonshredders. RBP II focuses on the riffle/run habitat because it is the most productive habitat available in stream systems and includes many pollution-sensitive taxa of the scraper and filtering collector functional feeding groups.

Collection of macroinvertebrates included quantitative and qualitative sampling methods. Quantitative sampling included triplicate sampling with a Surber sampler in riffles and runs. Qualitative sampling included rock picking for clinging individuals and netting individuals swimming within the water column. CPOM was collected from available detritus, leaves and sticks and individuals were counted until at least 50 individuals were obtained to evaluate the ratio of shredders to the total number of individuals collected. All macroinvertebrates collected are listed on data sheets reprinted in Appendix C. Table 9 and Exhibits 9 – 13 provide the macroinvertebrate survey results.

Table 9

MACROINVERTEBRATE MATRIX SCORES

Parameter	MF-1	MF-2	MF-3	MF-4	MF-5	MF-6	MF-7	MF-8	MF-9	MF-10
Taxon Richness	9	12	6	5	15	8	12	11	6	8
Family Biotic Index	7.14	7.28	7.54	6.41	7.32	7.93	6.88	7.74	7.58	7.83
Ratio of Scraper/Filterer	0.5	2.5	(0/0)	(4/0)	77	(29/0)	(44/0)	(105/0)	35.5	5.1
Ratio of EPT/Chironomidae	0.06	0.06	(0/20)	(0/6)	0.14	(0/1)	(0/42)	(0/6)	(0/20)	(0/8)
% Contribution Dominant Family	30	49	74	53	46	58	32	62	29	67
EPT Index	1	1	0	0	1	0	0	0	0	0
Ratio of Shredder/Nonshredder	0.24	0.69	1.00	0.45	0.02	0.89	(0/50)	0.06	0.50	0.04
Total Number Collected	104	159	145	121	167	151	129	170	124	113

Taxon richness is the total number of families present. Richness generally increases with increasing water quality, habitat diversity and habitat suitability. Taxon richness ranged from a low of 5 at the tributary site MF-4 to a high of 15 at mainstem site MF-5.

Modified Family Biotic Index (FBI) was developed to detect organic pollution and is based on the original species level index developed by Hilsenhoff in 1982. The modified FBI is a product of pollution tolerance values for family levels and the quantity of individuals within each family. Pollution tolerance values range from 0 to 10 for families and increases with pollution tolerance, that is, a higher FBI depicts a macroinvertebrate community under stress from degraded water quality. The most tolerant macroinvertebrate community was found at MF-6, and the community with the lowest FBI, possibly implying the most pristine water quality conditions was found at MF-4.

The ratio of scraper to filtering collector reflects the riffle/run community food base. The relative abundance of scrapers and filtering collectors in the riffle/run habitat is indicative of periphyton community composition, availability of fine particulate organic material and the availability of attachment sites for filtering. Scrapers increase with an increase in diatom abundance and a decrease in filamentous algae and aquatic mosses. Filamentous algae and aquatic mosses provide good attachment sites for filtering collectors and the organic enrichment often responsible for filamentous algae growth can also provide fine particulate organic material that is utilized by filtering collectors. Filtering collectors are also sensitive to toxicants bound to fine particles and should be the first group to decrease when exposed to steady sources of such bound toxicants. Hence, higher scores in this category generally indicate more pristine, less enriched water. Several sites received relatively high scores in this metric: MF-4 (ratio of 4:0), MF-5 (77:1), MF-6 (29:0), MF-7 (44:0), MF-8 (105:0), and MF-9 (36:1). Low scores, indicative of enriched conditions nurturing filter feeders, were found at the most downstream sites, MF-1 (1:2) and MF-2 (5:2).

The ratio of EPT (Ephemeroptera-mayflies, Plecoptera-stoneflies and Trichoptera-caddisflies) to Chironomidae (midges) reflects good biotic condition if the sensitive groups (EPT's) demonstrate a substantial representation. If the Chironomidae have a disproportionately large number of individuals in comparison to the sensitive groups then this situation is indicative of environmental stress. Few EPT representatives were found at any site (see EPT Index metric) and all scores in this metric are considered low.

Percent Contribution of Dominant Family uses the abundance of the dominant taxon relative to the total number of organisms as an indicator of community balance at the family level. High scores represent a benthic community dominated by one family. MF-3, a tributary site, had 74% of the collected individuals dominated by one family. The lowest scores were MF-9 (29%), MF-1 (30%) and MF-7 (32%).

EPT Index value summarizes the taxa richness within the taxa groups that are generally considered pollution sensitive and will generally increase with increasing water quality.

This metric is the total number of distinct taxa within the groups Ephemeroptera, Plecoptera and Trichoptera. As indicated earlier, there were very few EPT individuals collected at any site.

Ratio of Shredder functional feeding group relative to the abundance of all other functional feeding groups allows for the evaluation of potential impairment. Shredders are sensitive to riparian zone impacts and are good indicators of toxic effects when the toxic chemicals involved are adsorbed to the CPOM and either affect microbial communities colonizing the CPOM or the shredders directly (USEPA 1989). Pesticides and PCBs (polychlorinated biphenyls) are examples of these types of toxic chemicals. Fertilizers are not. Scores for this metric were quite varied between stations. Lowest scores were found principally in the upper reaches of McFadden Creek proper, including MF-7 (0:7), MF-5 (1:50), MF-10 (1:25) and MF-8 (3:50).

3.0 CONCLUSIONS AND RECOMMENDATIONS

This diagnostic study has examined the physical, biological and chemical health of McFadden Creek at its tributaries. In this study, key stream indicators of watershed health are judged to be coliform bacteria, nitrogen concentrations, suspended solids, the QHEI scores and FBI, the Family Biotic Index. Phosphorus concentrations were essentially identical among the stations, so that measure was judged not to distinguish between sites. The FBI was selected as the key benthic indicator as it incorporates both diversity and pollution tolerance. Recall that lower FBI scores are an indicator of an aquatic system under less stress. Table 10 reiterates these data for the ten stream sites sampled.

Table 10

SUMMARY OF TRIBUTARY HEALTH INDICATORS

Site	Subwatershed	*E. coli* (cfu/100mL)	Ammonia N (mg/L)	Nitrate N (mg/L)	Suspended Solids (mg/L)	Siltation	QHEI Score	FBI
MF-1	Mainstem	300	0.11	2.2	28	Normal	52	7.14
MF-2	Mainstem	280	0.16	2.2	35	Normal	63	7.28
MF-3	Tributary	180	0.54	1.5	16	Moderate	48	7.54
MF-4	Tributary	1,200	0.41	4.8	6	Normal	56	6.41
MF-5	Mainstem	380	0.34	1.6	76	Moderate	52	7.32
MF-6	Tributary	700	0.57	<0.05	83	Moderate	46	7.92
MF-7	Mainstem	150	<0.03	1.8	68	Normal	48	6.88
MF-8	Mainstem	240	0.15	3.3	120	Moderate	39	7.74
MF-9	Tributary	180	0.26	3.6	10	Moderate	42	7.58
MF-10	Tributary	23	0.81	3.5	3.5	Heavy	33	7.83

We used these data to rank these sites according to the level of ecological stress each was being subjected to, and, to recommend a relative ranking of subwatersheds on the basis of relative need for nonpoint source controls (Table 11). Categories of high, moderate and low priorities indicate Harza's opinion on relative need for agricultural nonpoint source controls. These categories are illustrated in color in Exhibit 14.

Table 11

**RELATIVE PRIORITIES FOR
AGRICULTURAL NONPOINT SOURCE CONTROL INVESTMENT**

Priority	Stations
High	MF-10 MF-4 MF-8 MF-9
Moderate	MF-7 MF-5 MF-6 MF-3
Low	MF-1 MF-2

REFERENCES

Harza Engineering Company. 1999. Quality Assurance Project Plan for Pigeon Creek Watershed Diagnostic Study and Stream Reach Characterization Evaluation Report. Revision 3. Prepared for IDEM, Evansville Water and Sewer Utility, and Four Rivers RC&D. October, 1999.

Hilsenhoff, W.L. 1987. An Improved Biotic Index of Organic Stream Pollution. Great Lakes Entomologist (20): 31-39.

McNab, W.H. and P.E. Ayers. 1994. Ecological Subregions of the United States. Report No. WO-WSA-5. Published by the US Forest Service. Washington, DC.

Plafkin, J. L. *et al.* 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish. EPA/444/4-89-001.

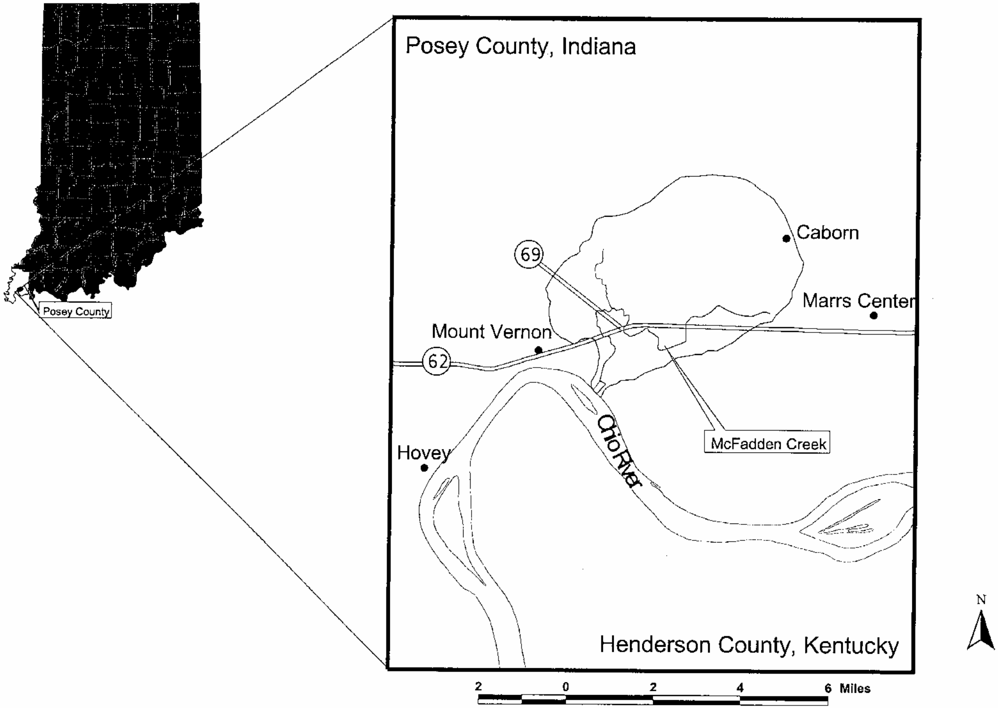
Rankin, E.T. 1989. The Qualititative Habitat Evaluation Index (QHEI): Rationale, Methods and Application. Ohio Environmental Protection Agency. Columbus, Ohio.

Scott, J.M. and M.D. Jennings. 1997. A Description of the National Gap Analysis Program. United States Geological Survey, Biological Resources Division, Moscow, Idaho. http://www.gap.uidaho.edu/About/Overview/GapDescription/.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1994. State Soil Geographic (STATSGO) Database for Indiana. U.S. Department of Agriculture, Natural Resources Conservation Service. Official Soil Series Description Data Access. http://www.in.nrcs.usda.gov/.

U.S. Environmental Protection Agency. STORET Water Quality Database, http://www.epa.gov/owowwtr1/STORET/.

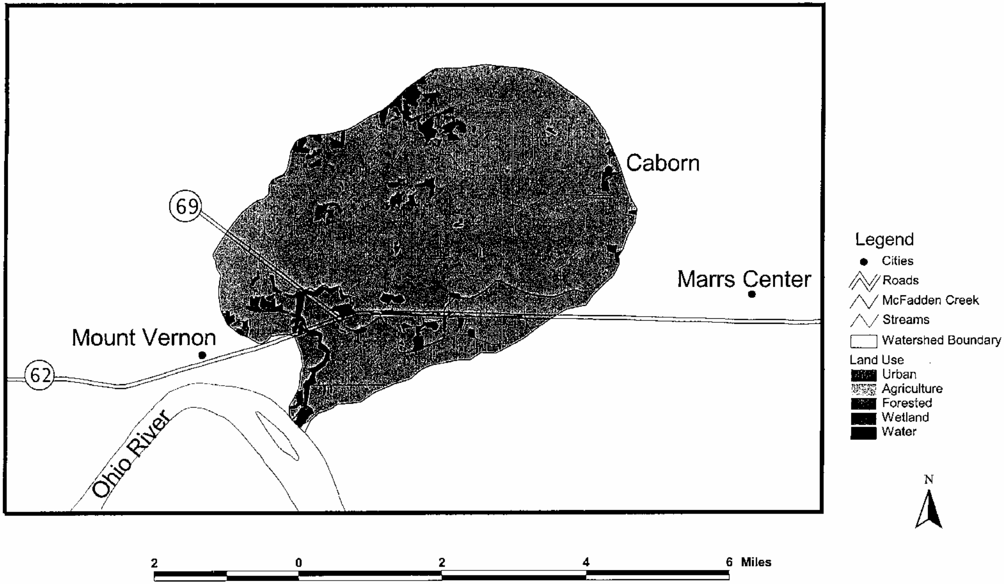
EXHIBITS



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

LOCATION MAP
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

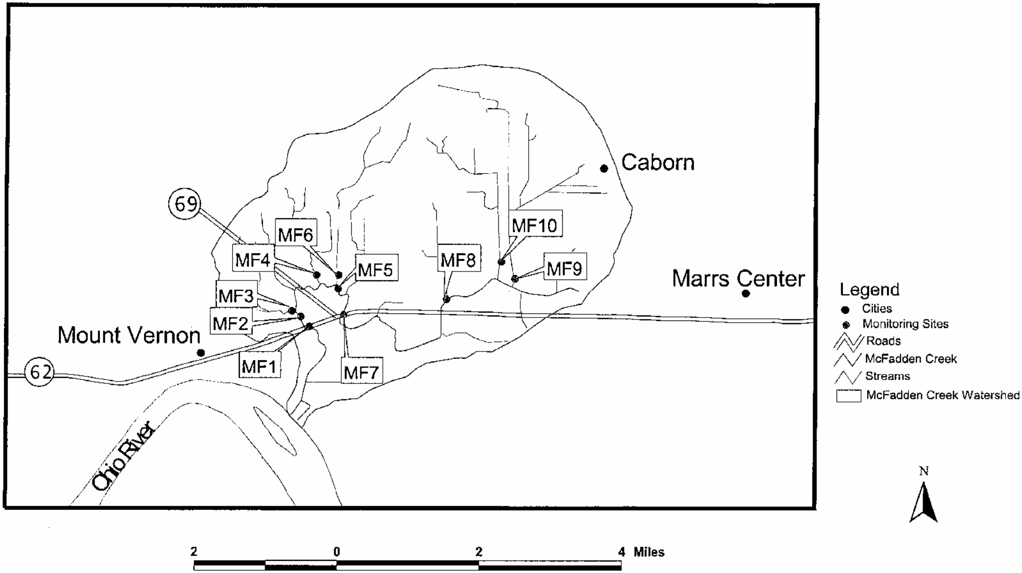
EXHIBIT 1



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

LAND USE MAP
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

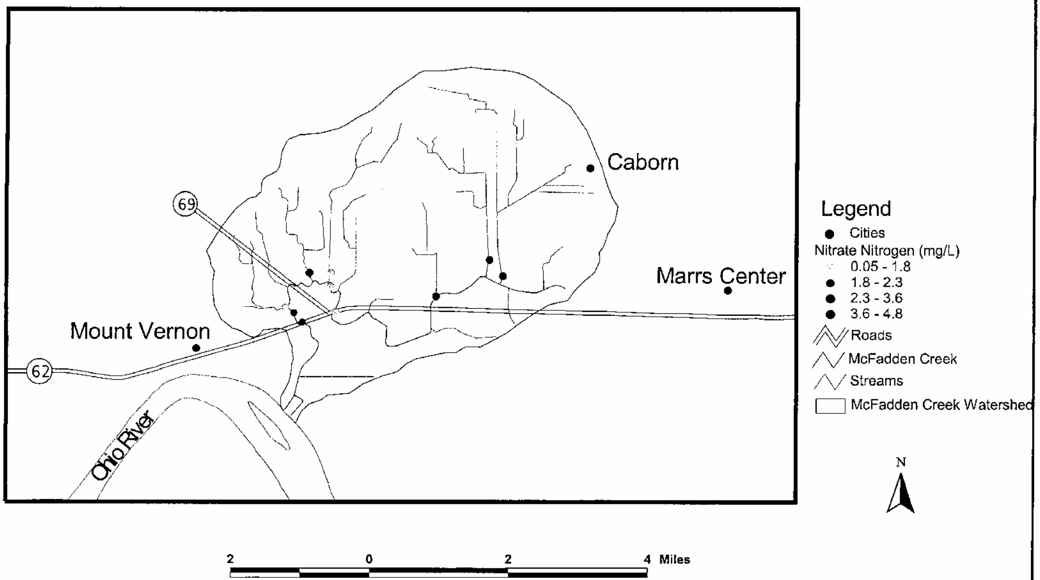
EXHIBIT 2



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

SAMPLING SITES
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

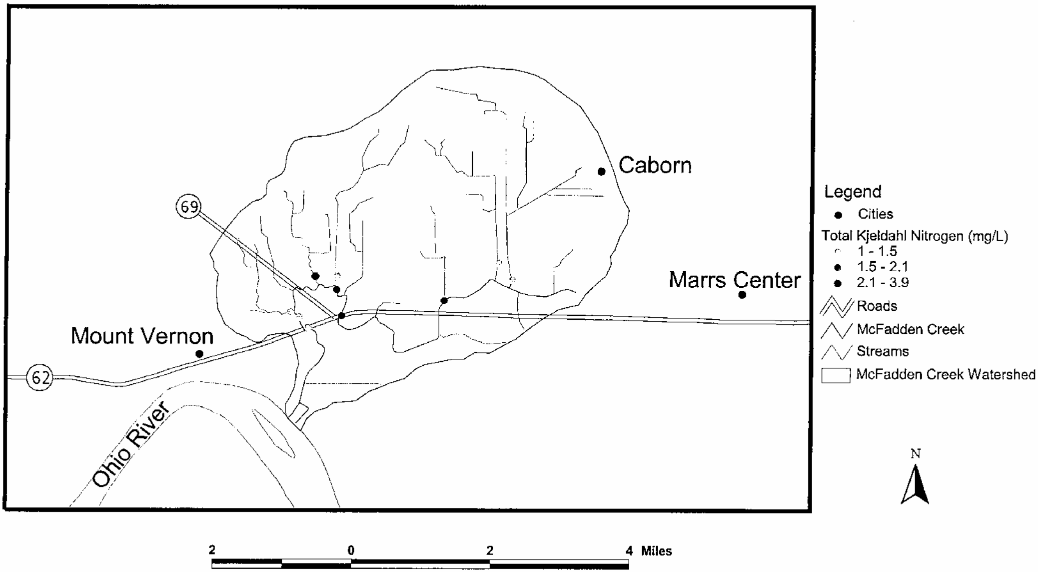
EXHIBIT 3



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

NITRATE NITROGEN
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

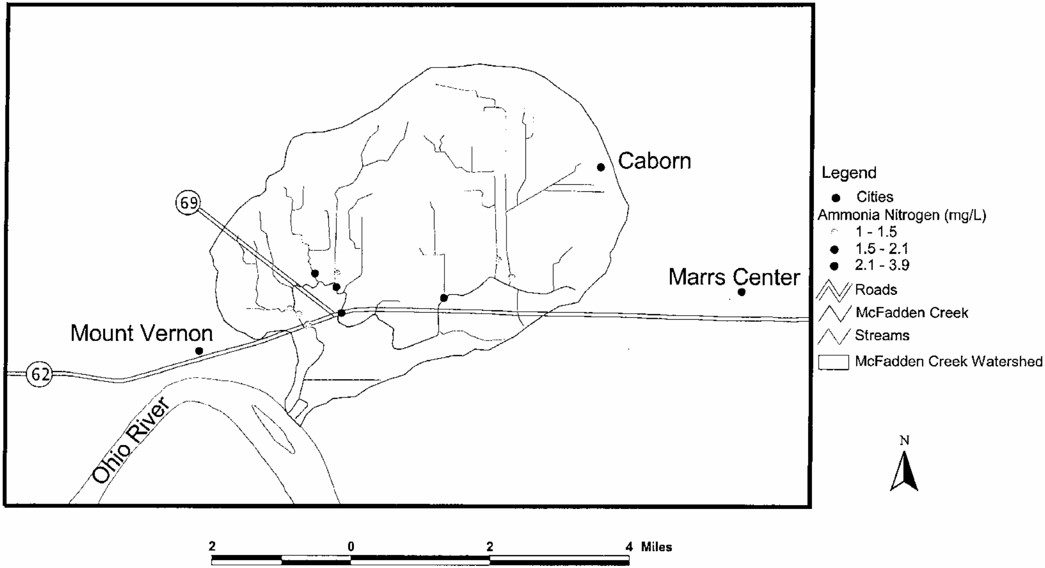
EXHIBIT 4



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

TOTAL KJELDAHL NITROGEN
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

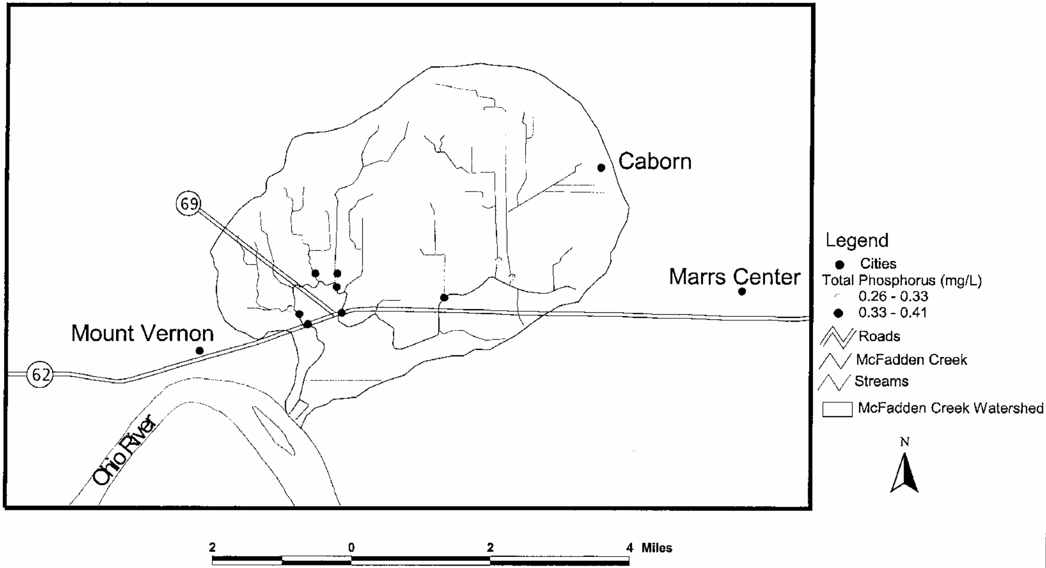
EXHIBIT 5



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

AMMONIA NITROGEN
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

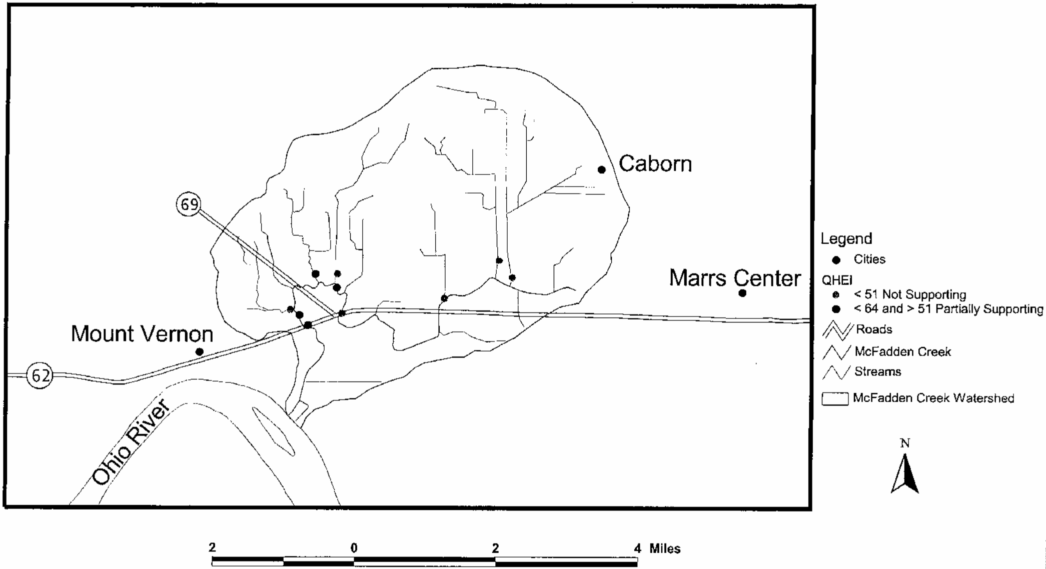
EXHIBIT 6



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

TOTAL PHOSPHORUS
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

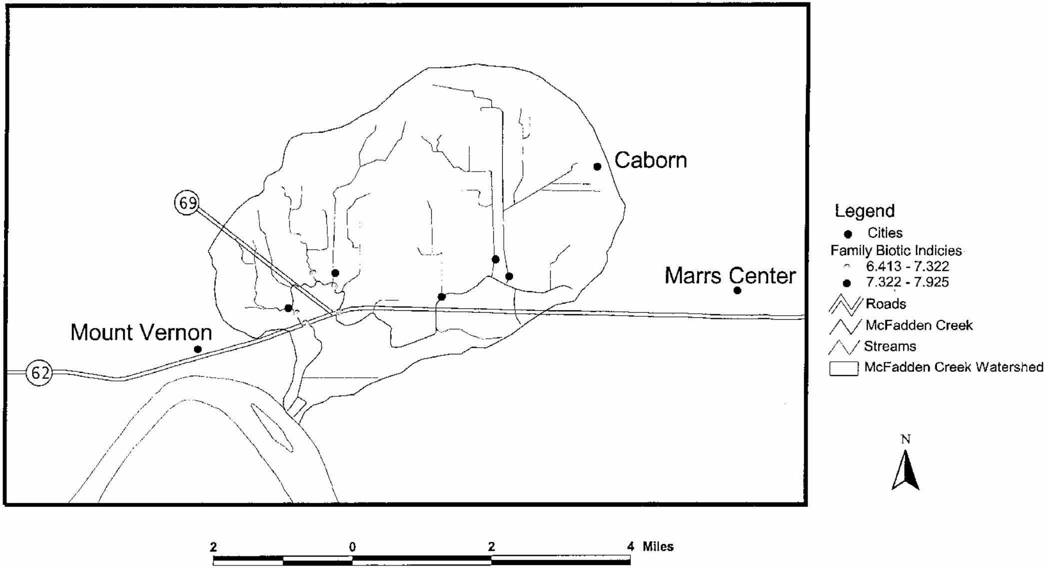
EXHIBIT 7



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

QUALITATIVE HABITAT EVALUATION INDICIES
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

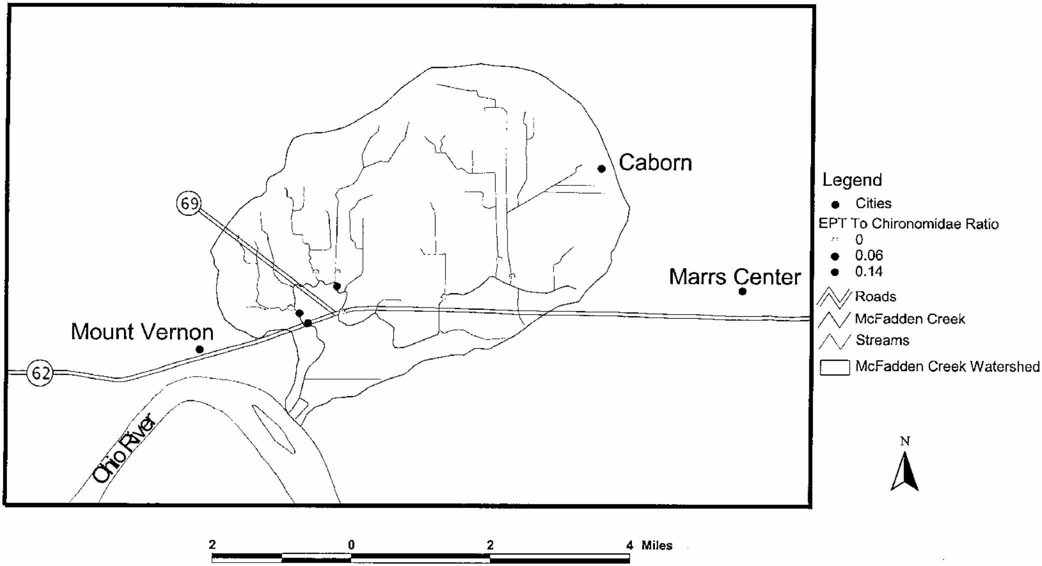
EXHIBIT 8



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

FAMILY BIOTIC INDICIES
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

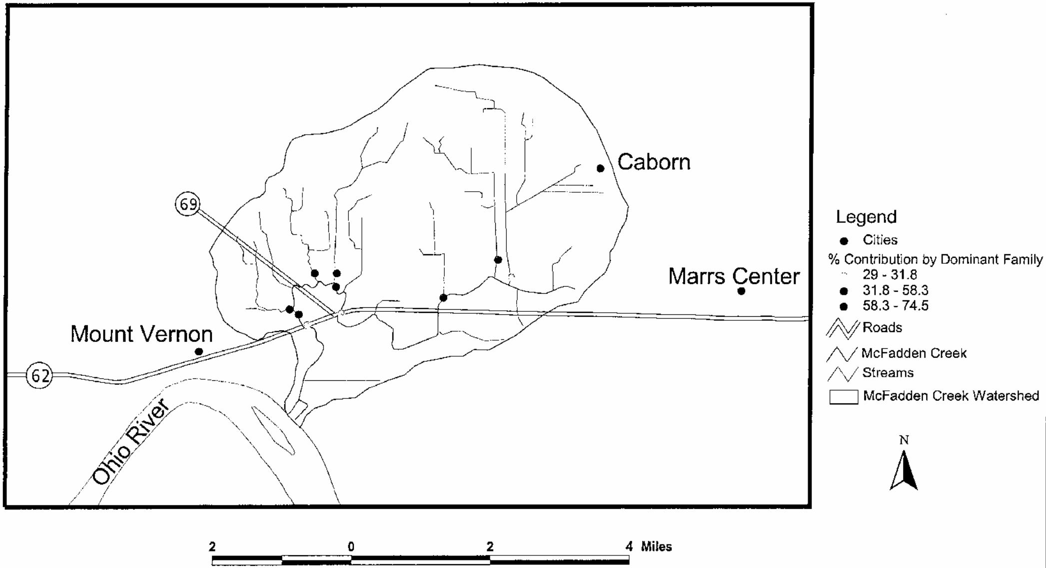
EXHIBIT 9



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

EPHEMEROPTERA, PLECOPTERA, TRICOPTERA TO CHIRONOMIDAE RATIO
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

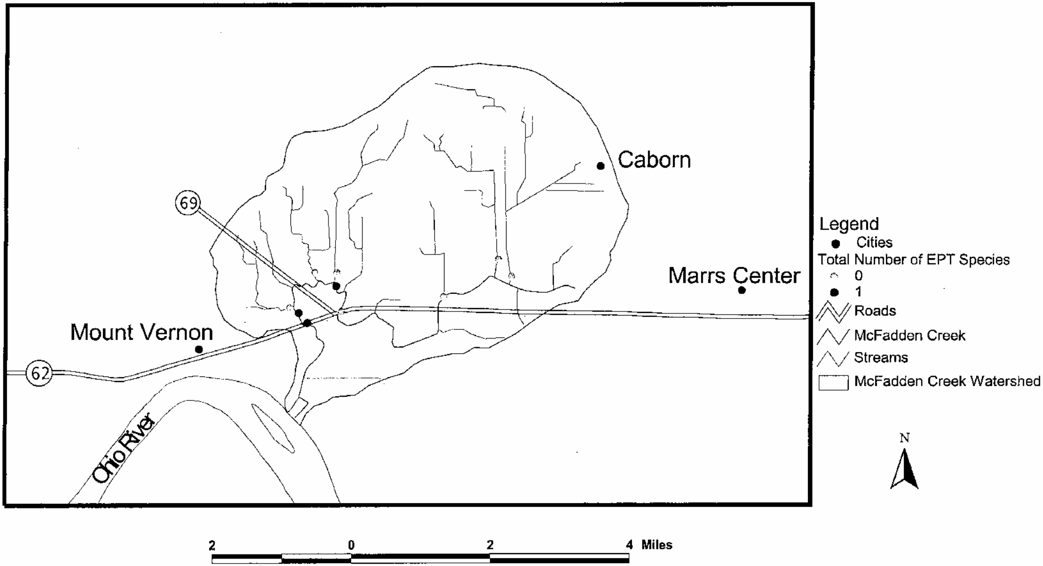
EXHIBIT 10



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

% CONTRIBUTION BY DOMINANT FAMILY
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 11

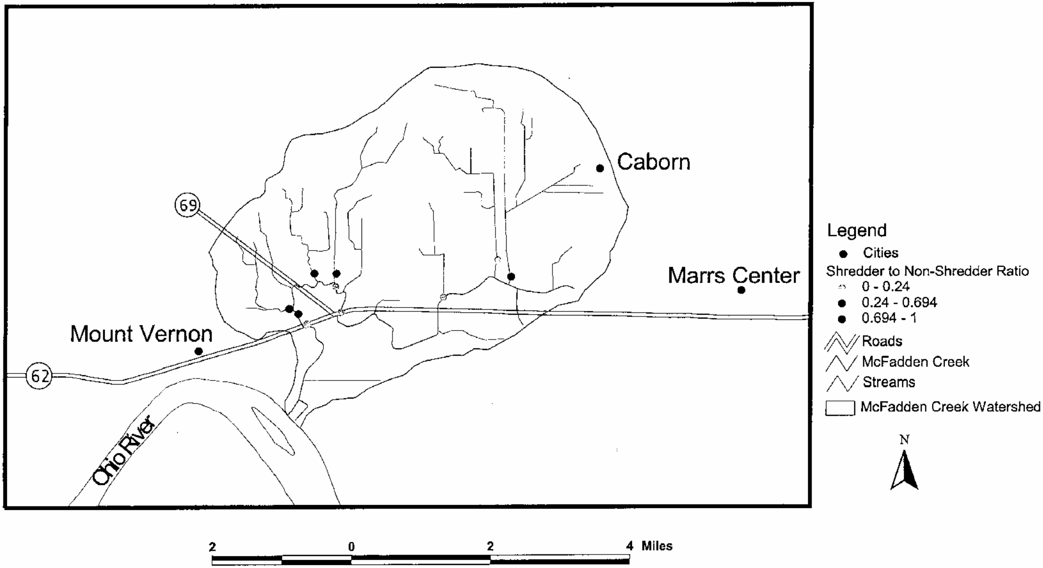


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

TOTAL NUMBER OF EPHEMEROPTERA, PLECOPTERA AND TRICOPTERA SPECIES

MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

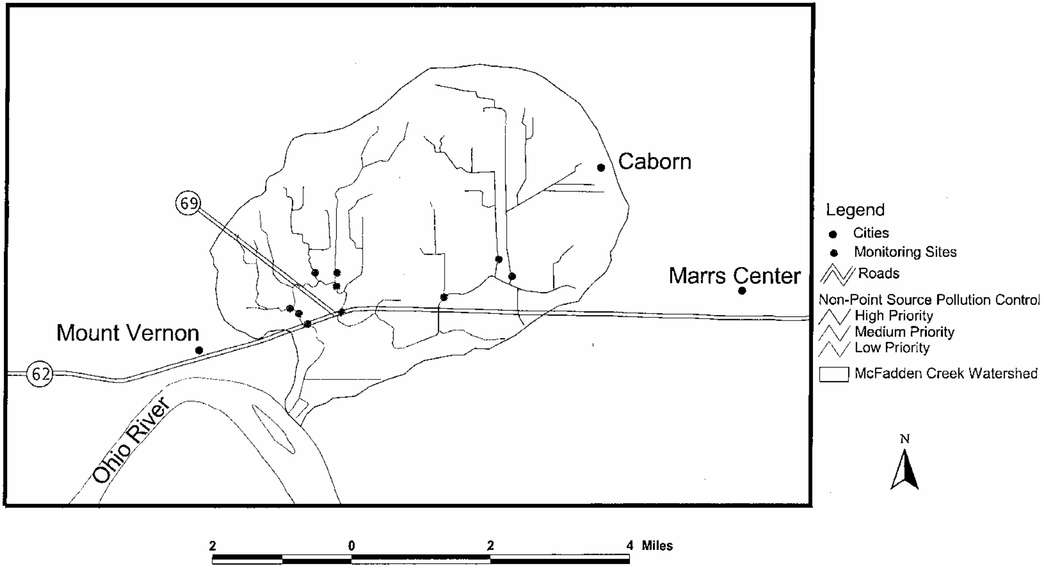
EXHIBIT 12



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

SHREDDER TO NON-SHREDDER RATIO
MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 13



RELATIVE PRIORITIES FOR AGRICULTURAL NON-POINT SOURCE CONTROL INVESTMENT

MCFADDEN CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 14

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT